X-Ray Tubes for High Frequency Coils

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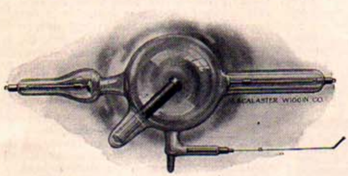
IN all the history of scientific achievement there has been perhaps no discovery of such a startling and revolutionary character as that of the X-Ray.

The *Electron theory,* which forms the basis of the chemistry and physics of our New Age has been formulated almost entirely from deduction made possible by the work of Roentgen and the Curies.



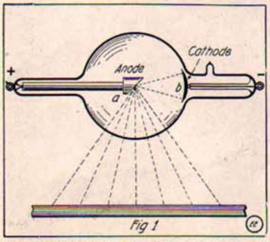
Standard Form of Single-Focus High Frequency X-Ray Tube. The First Powerful X-Ray Tubes Were Excited By a High Frequency Oscillator.

If we review the history of these discoveries we find that they have resulted from long series of researches dealing with the phenomena of electrical discharges in partial vacua.

The air pump was invented in 1650 by Otto von Guericke; by its use Sir W. Snow Harris, in 1834 was able to show that the spark-length of a given electrical machine increases in inverse ratio to the pressure of the gas thru which it passes. His tubes were exhausted to about one five-hundredth of an atmosphere, and the dischage took the form of a pencil of violet-pink light.

Geissler, in 1838, experimented with discharges in low vacua, and invented the beautiful tubes which bear his name. By improving the air-pump, he was able to withdraw all but one ten-thousandth of the original air from the glass tube, and change the color of the glow, in the electrified space from violet-pink to a pure white.

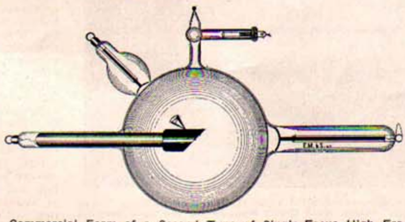
The invention of the mercury air-pump by Sprengel in 1865, made it possible for Sir William Crookes in 1878, to study electrical discharges in rarefied gases with pressures as low as *one one-millionth* of an atmosphere. He gave to the world the "Crookes tube," with which Lenard in 1894, proved the existence of the "Cathode rays," and from which in 1895, Roentgen accidentally discovered a new form of emitted energy which he tentatively called the "X-Ray."



The Simple X-Ray Tube Contains an Anode or Target "a" and an Aluminum Cathode "b." The Cathodic Electron Bombardment of Target "a" Causes X-Rays to be Produced At Right Angles or Downward As Shown.

We all recall the circumstances of this discovery. Roentgen was experimenting with a Crookes tube enveloped in an opaque cover, when he noticed a bright glow on a nearby card, coated with Platinum-Barium-Cyanid. The glow continued even when the uncoated surface of the card was presented to the tube, and further experiment showed that the interposition of the experimenter's hand between the covered tube and the fluorescent screen would cause a shadow-picture of the bones to appear upon the glowing surface.

The publication of Roentgen's discovery led investigators in all parts of the world to study the new phenomena. Static machines and Ruhmkorff induction coils were at first employed to excite the Crookes tubes; but the intensity of the resulting X-rays was not very great. In those days an induction coil giving a four-inch spark was regarded as exceedingly powerful. We know now that such an apparatus is entirely inadequate to the production of X-rays for any practical purpose.



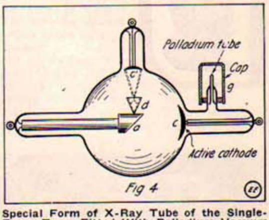
Commercial Form of a Second Type of Single-Focus High Frequency X-Ray Tube Shown Sectionally in Fig. 4. These Tubes Are Adapted to High Power Tesla or Oudin Coils.

Tesla and Elihu Thompson advocated high-frequency currents for X-ray generation, and in 1896 the Knott Apparatus Company of Boston designed the first practical commercial X-ray machine. It consisted of an open-core transformer, glass-plate condenser and Tesla coil, immersed in oil, and a rotary spark-gap not unlike those now used in Radio-telegraphy.

A few months later, the writer made the first practical high-frequency apparatus having solid insulation instead of oil, and suitable for therapeutic as well as X-ray work. The many types of high-frequency machines that are now made for physicians' use are but variations and improvements of this original apparatus.

At the present time the professional Roentgenologist uses almost exclusively powerful apparatus of the high-tension transformer type; the high-voltage, low-frequency, alternating current being rectified by a high-tension commutator operated by a synchronous motor. With such an apparatus and suitable X-ray tubes, a skiagram of the adult thorax or abdomen may be made in the *fraction of a second.*

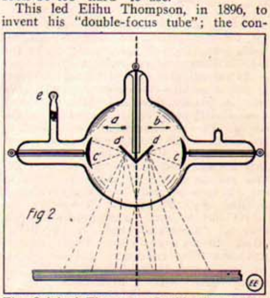
For the general practitioner, the dentist and the amateur experimenter, however, the high-frequency apparatus is still the most convenient and inexpensive device for exciting X-ray tubes, and produces results quite adequate to their respective needs.



Special Form of X-Ray Tube of the Single-Focus Type, Fitted With Palladium Vacuum Regulator and Focussing Mirror "C'", Also Copper Cone "d," for Dissipating Auxiliary Cathode Stream.

The construction of an X-ray tube is familiar to all:—in its simplest form it consists of a Crookes tube (as shown in Fig. 1), containing an anode or target (a), faced with platinum or tungsten, and a concave aluminum cathode (b). A high-voltage, unidirectional current flowing thru the tube causes streams of electrons to pass from the cathode to the target, which is set at an angle of forty-five degrees to the axis of the tube. The electronic stream ("Cathode rays"), is reflected at right angles and part of the energy is transformed into X-rays, which emerge from the glass in a divergent cone, as shown. Such a tube is not suited for use with alternating or oscillating currents, as a double set of rays would be produced; this would tend to melt the aluminum cathode and cause the absorption of the residual gas in the tube so that it would soon be too "hard" to use.

This led Elihu Thompson, in 1896, to invent his "double-focus tube"; the construction and operation of the Thompson double-focus tube is shown in Fig. 2.



The Original Thompson Double-Focus High Frequency X-Ray Tube Which Really Comprised Two Distinct Bulb Elements.

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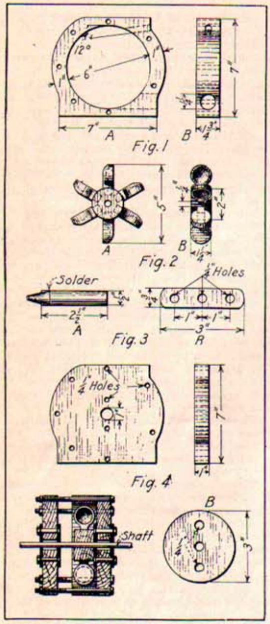
A SMALL WATER MOTOR FOR DRIVING DYNAMOS.

By W. E. Leach.

A water motor, owing to the variety of uses it may be put to, will find ready call among experimenters. It is not at all difficult to construct and below I describe one



Construction Details for a Small Water Motor Which Will Prove Useful In Driving Dynamos or Other Light Machinery.

that I made and used successfully to drive a dynamo, sharpen tools, as a drill, and also as a small lathe.

The first thing to obtain is the materials. These consist briefly of the following:—1 piece 2" x 8" x 10" plank (hard wood), 2 pieces 1" x 8" x 10" board (pine), some ¼" x ½" board (soft or hard wood)—7 5" x 3/16" bolts, 4 1½" x 3/16" bolts, 1 piece brass tubing ½" in diameter, 2½" long (for nozzle).

To begin with, cut a case from the piece of plank as shown in Fig. 1 A and B. Bore seven ¼" holes thru this as shown. At the bottom bore a 1¼" hole for an outlet. Then at the top, bore a ½" hole about 12° to the horizontal; this is the inlet. The rotating section is made up as shown in Fig. 2 A and B. The vanes or paddles are cut from ½" boards and of dimensions shown. They are hollowed out at the ends and are set into an axle cut from a piece of hard wood 1¼" x 2" with a ¼" hole thru the center.

To make the nozzle take the piece of brass tubing above mentioned and solder to it a cone shaped piece of tin as in Fig. 3—A. Now drive this into hole at top of case until its tip first comes to the inner edge.

Now for the sides, cut two pieces out of 1" pine as shown in Fig. 4. Bore 7 ¼" holes thru these to correspond to those in the case (Fig. 1). At the center bore a 1" hole, and about 1" away from the center in a perpendicular line, drill one ¼" hole on each side of this as shown. Now make two plates 3" in diameter and ¼" thick as shown in B (Fig. 4). Bore a ¼" hole in the center and about 1" to either side bore another ¼" hole. Make two plates of iron as in Fig. 3—B. Drill holes to correspond to those in the plates, Fig. 4—B.

Give all parts two coats of good water-resisting paint and when dry assemble as follows:—Place a plate (Fig. 4—B) on the outside of the sides, put a wad of packing soaked in oil in the 1" hole. Then place an iron strip (Fig. 3—B) on the inside of each side and bolt firmly together with two 1½" x 3/16" bolts. Drive a shaft thru the rotating part. Insert one end of shaft thru one side and then place inside of case. Put the 7 5" x 3/16" bolts thru and fasten the other side together. (In setting up, if some pitch is placed between the sides and case it will prevent any leakage.) Connect the motor to any faucet by a rubber hose and it is ready for work. If all parts were smooth and bored and cut accurately, little trouble will present itself and the motor will go buzzing around at first connection.

X-RAY TUBES FOR HIGH-FREQUENCY COILS.

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It is really a combination of two distinct tubes, as indicated by the heavy vertical dotted line. When the current passes in the direction of the arrow (b) X-rays are produced from the cathode and target (c and d) in the righ-hand half of the tube; alternations in the opposite direction, indicated by the arrow (a), produce a stream of rays from the left half of the tube. This is the most efficient form of high-frequency X-ray tube, as it uses both sets of alternations. It is now practically obsolete, however, as it was found that the two sets of X-rays overlapt and produced double outlines in the skiagram.

At the present time there are two types of X-ray tubes made for use with high-frequency currents. The one shown in Fig. 3 has a target of heavy copper faced with tungsten, and is mounted opposite the active cathode (c); when the current flows in the opposite direction the electronic stream from the small cathode (c[1]) becomes choked out and dispersed by the constricted glass neck (d), which acts, in a measure, as a valve, eliminating the inverse discharge.

Another type of modern high-frequency X-ray tube is shown in Fig. 4, in which the cathode rays from the small aluminum mirror (c[1]) focus inside a small copper cone (d), in which they are converted into heat and take no part in the production of the X-rays.

Tubes of these types may be operated by the current from a Tesla coil or from an Oudin resonator. In a previous article in the May issue of the ELECTRICAL EXPERIMENTER the writer has given details for the construction of apparatus of both these types.

When the Tesla coil is used its terminals are connected to the two aluminum cathodes (c and c[1]); the Oudin coil has but one active terminal which should be connected to the active cathode (c); the small cathode (c[1]) may be grounded, but this is not absolutely necessary.

X-ray tubes are spoken of as "hard" and "soft"—a "hard" tube is one which has been exhausted to a very high degree—(say, one-ten-millionth of an atmosphere) —a "soft" tube has a lower degree of exhaustion (between *one-five-hundred-thousandth* and *one-one-millionth* of an atmosphere). More current is needed to operate a hard tube, but it gives deep penetration and works more quickly. The soft tube, on the other hand, produces strong contrasts in the skiagram or fluoroscope.

Tubes have a tendency to become hard by use, the trace of residual air or gas being gradually driven out thru the intermolecular spaces of the glass by the electronic bombardment. So it is necessary to provide the tube with some means for replacing these lost ions at intervals.

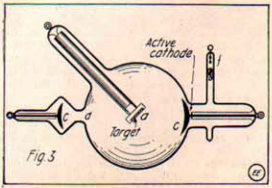
The first is of the thermic type and is now seldom used (see e, Fig. 2); it consists of a small bulb containing potassium chlorat sealed into the side of the X-ray tube. By heating this bulb with a match or spirit-lamp, a trace of oxygen is given off, which reduces the pressure in the tube to the required degree. The modern high-frequency tubes use the forms known as the "spark regulator" and the "osmotic regulator."

The first is the more common type and is shown in (f, Fig. 3). A platinum wire is sealed in the regulator tube which contains a gas-producing chemical, such as manganese dioxid, or sodium formate, f.

In practise a piece of E-shaped stiff brass wire set in a rubber handle is used to divert a portion of the current from the active terminal to the wire in the regulator; the heat from the current liberating the gas and softening the tube.

A regulator of the osmotic type is shown at (g, Fig. 4). It consists of an extremely small tube of metallic palladium sealed into the side of the X-ray bulb, the inner end of the metal tube being open while the outer end is closed. Ordinarily the tube is protected by a cylindrical glass cap. If the latter be removed, and the flame of a spirit-lamp be applied to the closed extremity of the palladium tube, hydrogen ions from the interior of the flame will be drawn thru the intermolecular spaces of the heated metal into the X-ray bulb.

Amateurs and physicians using X-ray outfits often desire to view considerable areas of the body simultaneously; this can be done only by using a large fluorescent screen and covering the X-ray tube with opaque material. Ordinary fluoroscopic screens are coated with barium-platinum-



One Form of Commercial High-Frequency X-Ray Bulb of the Single-focus Type, Utilizing An Active Cathode "C", Also a Small Cut-off Cathode "C[1]". The Inverse Cathodic Stream from "C[1]" Is Choked Off and Dispersed by the Constricted Glass Neck "D", Which Acts As a Valve.

cyanid and cost about $0.25 per sq. inch. A very good screen may, however, be easily made by evenly coating a sheet of white cardboard with a solution of sodium silicat and immediately sifting on it finely powdered calcium tungstat. Gently raise the screen on its edge and tap it to shake off the excess of tungstat; then allow to dry. A still simpler experimental screen may be made by painting a card several times with a strong solution of quinine bi-sulfate.